Electrical Stimulation of the Soft Palate

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Recent years have seen a resurgence of interest in what Shelton (*22*) has termed "physical therapy techniques" in the treatment of velopharyngeal incompetency (*12*, *25*, *32*). Yules and Chase (*32*) and Tash et al. (*25*) investigated training programs for the development of voluntary pharyngeal wall movements. The development of such programs was preceded by numerous reports of changes in pharyngeal wall movements following obturator insertion (*1*, *6*, *20*, *28*).

Tash et al. (*25*) used tactile stimulation to elicit movement of the pharyngeal walls as the first step in a program designed to teach subjects to produce these movements voluntarily. The results indicated that children with adequate closure were able to produce the criterion voluntary wall movements on phonation of /ɑ/; however, subjects with closure deficits were not able to learn the task as well and showed no improvement in closure at the end of the training program.

Yules and Chase (*32*) applied electrical stimulation first to the palate and then to the posterior and lateral pharyngeal walls in patients with velopharyngeal incompetency in the first phase of an extensive training program which was devised to (1) obtain "voluntary pharyngeal contractions," and (2) automate these contractions into spontaneous speech. Subsequent phases of the training program involved home practice with Q-tips and a mirror and the use of an operant conditioning device to incorporate the movements into speech. The first published report (*32*) was optimistic but did not allow objective evaluation of the nature and degree of change in the behavior of velopharyngeal musculature. Furthermore, a follow-up report (*30*) indicated that only one of the seven subjects available for re-evaluation a year after the training program "demonstrated a significant reduction in nasality in his speech."

Yules and Chase (*32*) pointed out that ". . . any object for touching the pharyngeal wall might prove effective" in eliciting movement. In discussing the results of their own study, Tash et al. (*25*) suggested that another

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form of stimulation—such as electrical stimulation—might be more effective than tactile stimulation. Thus the question was raised regarding the differential effects of tactile and electrical stimulation of velopharyngeal musculature in attempting to obtain behavioral changes in this musculature.

WHY ELECTRICAL STIMULATION? Within the field of physical therapy, one of the common uses of electrical stimulation has been to strengthen and/or "re-educate" weak muscle which is normally or partially innervated (*4, 5, 8, 10, 11, 18, 21, 26*). The technique presumes the stimulation of proprioceptive pathways (*8*) when the patient "seems unaware of how to use the muscle" (*18*) after prolonged disuse.

A regimen of electrical stimulation therapy designed to effect hypertrophy and increase strength of palatal and/or pharyngeal musculature through physical exercise might be preferred over other types of programs of physical exercise on the following bases:

a. Muscle contraction resulting from electrical stimulation to the motor nerve constitutes active exercise of the muscle, as opposed to passive movement. Active physical exercise has long been noted to be of significantly greater therapeutic benefit than passive movement (*9, 27*).
b. When a muscle contracts in response to electrical stimulation to the motor nerve, more nerve fibers fire than in a voluntary contraction of the muscle (*2, 24*).

Purpose of Study

The purpose of the present study was to determine whether palatal elevation could be elicited by permucosal electrical stimulation applied to the oral surface of the soft palate.[1] Specifically, the experimental questions were,

1. Can palatal elevation be elicited in normal subjects by monopolar application of a low intensity, surged alternating current applied to the oral of the soft palate?[2]
   a. Does electrical stimulation result in palatal elevation which cannot be elicited by simple tactile stimulation (application of a probe)?

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[1] Although previous work with electrical stimulation of velopharyngeal musculature (32) included stimulation of both the soft palate and the pharyngeal walls, the present study was limited to investigation of the effects of tactile and electrical stimulation of the soft palate. The primary reason for exclusion of pharyngeal wall stimulation was to limit the number of variables. It is conceivable that stimulation of the soft palate may elicit movement of the posterior and lateral pharyngeal walls. Lateral cinefluorography of the mid-sagittal plane allows examination only of the movement of the posterior wall, and film analysis in the present study included such examination. Lack of a satisfactory means of assessing lateral wall movement constituted a second reason for the exclusion of pharyngeal wall stimulation from this study.

[2] Surface electrical stimulation, as opposed to stimulation through needle electrodes, was chosen for two reasons: (1) The only other study of electrical stimulation applied to the velopharyngeal musculature (that of Yules and Chase, 32) used surface stimulation. (2) Ultimate development of electrical stimulation as a "clinical tool" for use in cases of velopharyngeal incompetency would require a technique that would be acceptable and tolerable to patients, particularly children. Needle electrodes would not fulfill this requirement, although Fritzell (7) was successful in eliciting contraction of the levator with the use of needle EMG electrodes.

b. Does the amount of elevation obtained with electrical and tactile stimulation vary with the point of stimulation?
c. How does the amount of elevation obtained on electrical stimulation vary in relation to strength of current?
d. What is the relationship between that strength of current at which the subject detects the presence of the electrical current and that strength of current at which palatal elevation is first elicited?
e. How does the amount of elevation obtained on tactile stimulation compare with that shown on a non-speech maximum closure task? On a speech task?
f. How does the amount of elevation obtained on electrical stimulation compare with that shown on a non-speech maximum closure task? On a speech task?

In addition,

2. How do the answers to the above questions differ between normal subjects and subjects exhibiting pathological conditions of the velopharyngeal mechanism?

It should be noted that the questions asked relate to whether electrical stimulation results in palatal movement in a single experimental session, not over a period of time. Before effects over time could be studied, it was necessary to determine whether surface electrical stimulation of tolerable intensity levels could indeed elicit palatal movement.

Method

Subjects. The subjects in this study have been described in detail elsewhere (*17*). They were five speakers demonstrating velopharyngeal closure for speech in the presence of repaired palatal clefts, five speakers demonstrating velopharyngeal incompetency for speech, and ten subjects without palatal pathologies and with speech defects. (One of the normal subjects previously described (LY) had to be eliminated because of a hyperactive gag reflex.) The subjects with velopharyngeal incompetency for speech (as judged by three experienced speech pathologists) included two with submucous clefts, two with congenitally short palates, and one with a repaired unilateral cleft lip and palate (Von Langenbeck repair). None of the subjects had undergone pharyngeal flap surgery.

Instrumentation for Electrical Stimulation of the Soft Palate. For stimulation of the soft palate, a pencil electrode designed for intraoral use (Figure 1) was connected to the AC output terminal of a low voltage therapeutic generator, TECA Model SP5 (Teca Corporation). The output waveform of the SP5 was modified so that it would approximate the faradic waveform usually associated with motor nerve impulses (*23*). The duration of each faradic pulse was approximately 250 microseconds. The modified waveform possessed the rapid rise-time characteristic recommended by Dobner (*4*) and Watkins (*29*) for stimulation of innervated musculature. For stimulation of the soft palate, the faradic current was surged, as recom-

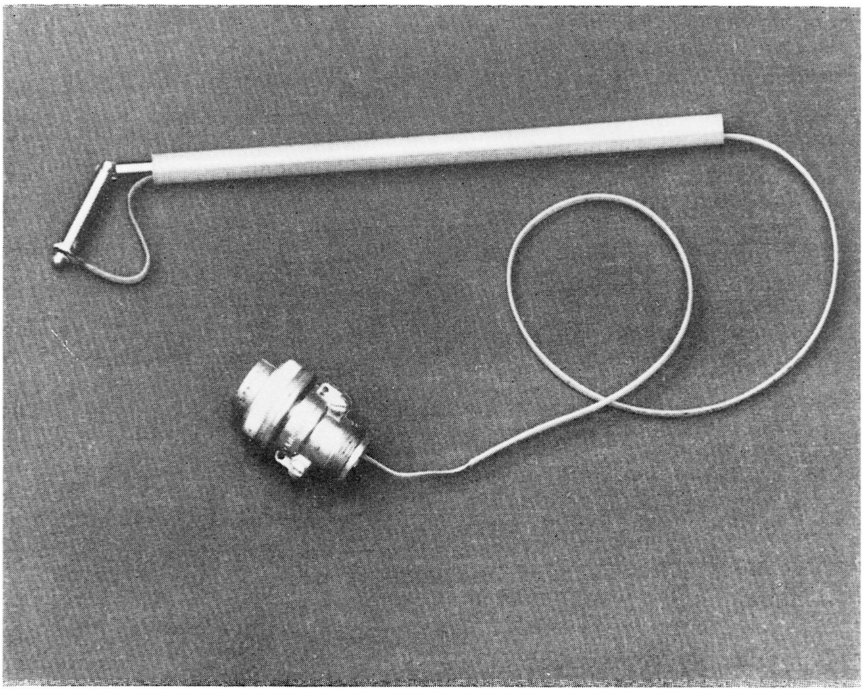

FIGURE 1. Intraoral stimulating electrode.

mended by Brazier (*3*), Reiner (*19*) and Morrissey (*16*). With a surged current, intensity builds to a maximum over a series of pulses and then decreases at the same rate. The maximum intensity values and the number of surges per minute are pre-set by the experimenter.

The intraoral stimulation electrode (Figure 1) consisted of three parts: an insulated steel shaft with an elbow joint allowing adjustment of the angle of the end of the shaft; an electrically-insulated subminiature absolute-pressure transducer (SAPT Model MM-BW); and an uninsulated, mushroom-shaped silver tip approximately ⅜-inch in diameter. The SAPT was mounted on the end of the steel shaft with a silicone rubber adhesive (Silastic 731 RTV) and was connected to an Offner 481-B preamplifier and 482 amplifier. The output of the amplifier was connected to one channel of a four-channel Offner Dynagraph, Model 504-A, ink-writing recorder. The SAPT was calibrated so as to prevent sensitivity to the breath stream and intraoral temperature changes. The transducer was included in the apparatus to allow regulation of the force with which the stimulating electrode was applied to the palate. The silver probe (electrode tip) was mounted on the diaphragm or pressure-sensitive side of the transducer and connected by an insulated wire to the output of the SP5 generator.

The dispersive electrode consisted of a 2″ by 3″ gauze-covered plate which was moistened and taped to the arm of the subject.

Instrumentation for Cinefluorographic Films. The cinefluorographic equipment used in this study has been previously described by Moll (*14*).

Procedure for Cinefluorographic Filming of Behavior Sample. The conditions comprising the "behavior sample" in this study have been previously described (*17*). Briefly, they consisted of (1) rest, (2) blowing on manometer with bleed valve open, nostrils open condition (see Morris, *15*), (3) repetition of the bisyllable /mɑmɑ/, and (4) repetition of the bisyllable /fufu/. Because cinefluorographic films were taken simultaneously with the electrical stimulation of the palate, the behavior sample was necessarily limited in size to minimize the radiation dosage.

Procedure for Determination of Sensitivity to Surged Faradic Current. *A. Orientation to the Procedure.* The electrical stimulation apparatus was explained to the subject. He was told that, during the experiment, a mild electric current would alternately be turned on and off in the intraoral probe, and that when the current was "on" he might feel a slight tingling sensation or he might not feel anything at all. At this point, the dispersive electrode was attached and the fingertip threshold of sensitivity to the current was established using the index finger. These thresholds ranged from 0.5 to 1.5 ma across subjects.[3]

B. Loci of Stimulation. Sensitivity to the surged current was determined at three points on the soft palate: (1) the levator eminence, or the point which approximated the location of the eminence in normal subjects; (2) a point approximately one-half the distance between the levator eminence and the left anterior faucial pillar; and (3) a point approximately one-half the distance between the levator eminence and the right anterior faucial pillar. The latter two loci were selected for proximity to the points of insertion of the levator palati into the soft palate.

C. Determination of Sensitivity and Discomfort Thresholds. Following orientation of the subject and attachment of the dispersive electrode, the sensitivity of the subject to the surged current was determined at each point of stimulation on the soft palate. Thresholds were established at each locus of stimulation for (1) awareness of the presence of the current, and (2) discomfort. The procedure was carried out twice to ensure reliability of the thresholds obtained.

Mean thresholds of sensitivity and discomfort, with accompanying standard deviations, are shown for each subject group in Table 1. No con-

[3] Determination of threshold of sensitivity to the stimulating current on the fingertip was originally included in the procedure as part of the effort to replicate, where feasible, the procedures of Yules and Chase (32). The latter investigators determined the threshold of feeling of their stimulating current on the fingertip, then halved the obtained value to determine the milliampere level to be used in intraoral stimulation. Early in the course of the present study, it became apparent that intensity levels derived by halving the fingertip thresholds were not suitable for palatal stimulation. Nevertheless, the procedure of establishing fingertip thresholds was continued in the interest of (1) allowing the subjects to become familiar with the current before the electrode was placed in the mouth, and (2) allowing observation of the variation in thresholds across subjects.

TABLE 1. Palatal thresholds of sensitivity and discomfort in milliamperes (ma).

	sensitivity			*discomfort*		
	right	*midline*	*left*	*right*	*midline*	*left*
A. *Normal subjects* ($n = 10$)						
range	1.0–3.0	1.0–2.5	1.0–2.5	2.0–5.0	2.0–5.0	1.75–5.0
mean	1.90*	1.77	1.82	3.85	3.67	3.67
standard deviation	.49	.45	.47	1.08	1.24	1.20
B. *Subjects with palatal pathologies and velopharyngeal competency* ($n = 5$)						
range	1.5–3.0	1.75–2.5	1.5–3.0	2.5–4.5	3.0–4.5	3.0–4.5
mean	2.15	2.05	2.05	3.75	3.90	3.90
standard deviation	.54	.12	.16	.84	.73	.73
C. *Subjects with palatal pathologies and velopharyngeal incompetency* ($n = 5$ *for sensitivity thresholds, 4 for discomfort thresholds*)						
range	1.25–3.0	1.5–3.0	1.5–3.0	2.5–4.0	3.0–4.5	2.5–4.0
mean	2.0	2.0	2.10	3.5	3.94	3.62
standard deviation	.57	.52	.49	.61	.55	.68

* It should be noted that the ma meter on the SP5 could be read only to the nearest .5 ma. Therefore, mean thresholds and standard deviation values should be viewed accordingly.

sistent trends were detected across subject groups, across sites of stimulation, or for different age groups.

PROCEDURE FOR ELECTRICAL AND TACTILE STIMULATION OF THE SOFT PALATE. *A. Tactile Stimulation Only.* To determine whether degree of palatal elevation in response to tactile stimulation was related to the amount of force with which the probe was applied, one normal subject (aged 13) was selected to receive tactile stimulation only. This subject's palate was stimulated at the midline only with taps at the successively greater forces of 50, 75, 80, 100, 130, 140, 180, and 270 grams.

B. Intensity of Current for Electrical Stimulation. The original procedural plan was for the intensity levels of the stimulating current to be determined individually for each subject according to that level which was first observed to elicit palatal elevation as the subject was viewed cinefluoroscopically (in preparation for the actual experimental procedure). A second level was to be selected to approximately double the first level, without exceeding the threshold of discomfort. However, when the cinefluorographic films of the first two subjects were viewed, it became apparent that neither of the stimulation levels thus selected were consistently resulting in palatal elevation during the actual running of the experiment. Therefore, the remaining 17 subjects were randomly divided into two groups:

(a) 9 subjects received stimulation at one level below the threshold of discomfort and one level above this threshold;

(b) 8 subjects received stimulation at two levels, both of which exceeded the threshold of discomfort.

C. Electrical versus Tactile Stimulation. The stimulating electrode served as both the electrical stimulator (current on) and the tactile stimulator (current off). The subject was not told when the current was on or off once the thresholds of sensitivity and discomfort had been established. The tactile stimulation thus served as a "placebo" condition.

The procedural plan was for each subject to receive two tactile stimuli and two electrical surges (surge rate: 12/min) at each site of stimulation for each intensity level. For each subject, the order of presentation of the stimuli (taps or surges first) was randomized across sites of stimulation. The sequence of stimulation sites (left, right, midline) was randomized across subjects. The sequence was changed from the first set of stimuli (first intensity level) to the second.

The pressure transducer/write-out system was included in the instrumentation to allow regulation of the force with which the electrode was applied to the palate. A standard force of 100 grams was selected for use in both electrical and tactile stimulation. The write-out system was calibrated so that 100 grams force (gf) corresponded to 1 cm on the graph. The system was re-calibrated after each use. The grams force read-out was monitored carefully during the procedure.

Procedure for Judgment of Responses to Stimuli. Two judges viewed each cinefluorographic film in order to identify palatal movement responses to the tactile and electrical stimuli. Each judge viewed each film independently at least twice, with a time interval of not less than one week between the two viewings. The two judges' impressions were compared, and the judges then viewed together those films on which they had disagreed. Only those palatal movements which both judges agreed were responses to stimuli were recorded as such. Each identified response fit one or more of the following patterns:

(1) The soft palate moved up and back, away from the probe, after the stimulus had been delivered,

(2) The superior surface of the soft palate showed a definite "bulging" or "humping" while the inferior surface stayed in contact with the probe,

(3) The soft palate and probe moved together in a superior-posterior direction, but the soft palate remained in an elevated position after the probe was removed.

Analysis of Cinefluorographic Films. The technique for analyzing the cinefluorographic films was similar to that used by Moll (*14*). The two film analysis measurements used in this study and the standard errors of measurement for each have been previously described (*17*).

Results

Behavior Sample. The four conditions comprising the behavior sample were originally included in the experimental procedure in order to allow comparison of the measures of velopharyngeal opening (VPO) and velar height (VH) under these conditions with those on responses to tactile and electrical stimuli. However, the behavior sample itself yielded data worthy of note. These data have been reported and discussed previously (*17*).

Tactile Stimulation Only. The results obtained on the one normal subject who received tactile stimulation only were essentially negative. Stimuli of successively greater gf values did not result in a consistent pattern of successively greater VH values or smaller VPO values.

Alternating Tactile and Electrical Stimulation. The majority of subject (11 of the 19), regardless of type, showed only sporadic response to tactile and electrical stimulation. The typical pattern among these subjects consisted of 2 or 3 palatal elevations occurring randomly during the stimulation procedure.

Two subjects of the velopharyngeal incompetency group, both of whom showed palatal elevation in speech, and one subject of the velopharyngeal competency group showed no response to any tactile or electrical stimuli.

Five subjects showed patterns of consistent responses to electrical stimulation but inconsistent response to tactile stimulation. Two (DM and GM) were from the normal subject group, two (JB and CR) from the velopharyngeal competency group, and one (CD) from the velopharyngeal incompetency group. The results on these five subjects are summarized in Table 2. None showed a trend for greater VH values (or smaller VPO values) with higher intensity of electrical current or greater gf values. VH values on responses to electrical stimulation fell between those on /mɑmɑ/ and those on /fufu/. Subjects with palatal pathologies showed more consistent and/or greater palatal elevation responses to stimulation on the left and right sides of the palate than at the midline.

Two of the eleven subjects who failed to show consistent responses to tactile or electrical stimuli did exhibit an interesting phenomenon in association with electrical stimulation. LC of the velopharyngeal competency group and KH of the velopharyngeal incompetency group showed head movements (away from the probe) in response to electrical stimulation despite the head holding apparatus. In both subjects, these head movements were not associated with palatal movement: Palatal position remained unchanged while the head moved up and back, away from the probe.

Summary of Results of Electrical and Tactile Stimulation. (1) The majority of subjects (11 of 19), regardless of type, showed only sporadic responses to tactile and electrical stimuli. However, 5 subjects showed patterns of systematic response to electrical stimulation.

(2) Differences in response in relation to strength of current appeared to be individual to each subject.

TABLE 2. Results obtained on five subjects showing systematic response to electrical stimulation.

subject description	*stimulation levels*	*stimulation of velopharyngeal closure*	*relation among VH values on stimulation, speech and blowing*	*differences in response among sites of stimulation*
GM (normal)	Both levels above threshold of discomfort.	Higher level resulted in VP closure, lower level did not.	VH values on stimulation fell between those on /mama/ and those on /fufu/ and below that on blowing.	No consistent differences..
*DM (normal)	Stimulation levels at and above threshold of discomfort.	One stimulus at higher level (at midline) elicited VP closure.	VH values on stimulation fell between those on /mama/ and those on /fufu/ and below that on blowing.	Stimulation on the right elicited elevation but with lower VH values and greater VPO valEes than did stimulation on the left and at the midline.
*JB (repaired bilateral cleft, VP competency for speech)	One level below threshold of discomfort, one above.	Higher level resulted (inconsistently) in VP closure.	VH values on stimulation fell between those on /mama/ and those on /fufu/ and below that on blowing.	Stimulation on left and right sides of palate resulted in greater VH values than did stimulation at the midline.
*CR (repaired unilateral cleft, VP competency for speech)	Stimulation levels at and above threshold of discomfort.	Inconsistent VP closure on responses to both levels of stimulation.	VH values on stimulation fell between those on /mama/ and those on /fufu/ and below that on blowing.	Stimulation on left and right sides of palate resulted in greater VH values than did stimulation at the midline.
CD (inadequate palatal length, minimal palatal movement in speech, VP incompetency)	Stimulation levels at and above threshold of discomfort.	Responses to the two stimulation levels similar, with no occurrence of VP closure.	VH values on stimulation similar to those on /fufu/.	Responses to stimulation occurred only with stimulation on left and right sides of palate, no response to stimulation at the midline.

* DM, JB, and CR showed less than 100% consistency in responding to electrical stimuli. DM responded only sporadically at the first stimulation level, and did not respond to the first stimulus at the higher intensity on the left. JB showed no response to the first stimulus exceeding the discomfort threshold but did show palatal elevation in response to the second application of the identical stimulus and to all other stimuli exceeding the discomfort threshold. CR failed to show a response to three of the stimuli exceeding the discomfort threshold although she had consistently shown response at a lower intensity. The most feasible explanation for this less-than-100% consistency in response appeared to be possible failure to place the probe tip flat against the palate.

(3) There was no indication of a relationship between force of application of the probe to the palate and either occurrence or height of palatal elevation responses.

(4) Two subjects from the velopharyngeal incompetency group and one subject from the velopharyngeal competency group showed no responses to any tactile or electrical stimuli.

(5) Velar height values on the palatal elevation responses to electrical stimulation tended to fall between those on /mɑmɑ/ and those on /fufu/.

(6) The three subjects with palatal pathologies who showed systematic response to electrical stimulation showed a trend of greater and/or more consistent response to stimulation on the left and right than on the midline of the palate.

Discussion

Tactile Stimulation. The present results indicate that simple tactile stimulation of the oral surface of the soft palate, regardless of type of subject and site or force of stimulation, does not systematically result in palatal elevation. Further, within the range of force used in this study (30–370 gf), no relationship could be detected between the force of stimulation and either (1) frequency of palatal elevation responses, or (2) the criterion measures of velopharyngeal opening and velar height.

There is the question of whether the results reported here are in contradiction to the results of other studies involving tactile stimulation of velopharyngeal structures (*1*, *6*, *20*, *25*). The primary distinction between the present investigation and previous studies involving tactile stimulation is that the stimulation regimen in the present study was not carried out over a period of time. The increase in mesial movement of the pharyngeal walls reported by a number of investigators (*1*, *6*, *20*) after a period of obturator use reflects the results of what is essentially long-term tactile stimulation of the lateral and posterior walls. Thus, both the studies of Tash et al. (*25*) and those investigators reporting on the results of obturator reduction programs were concerned with tactile stimulation over time, and cannot be refuted on the basis of the negative results of the present study.

Electrical Stimulation. The results obtained indicate that the technique of electrical stimulation as used in this study cannot be relied upon to produce palatal elevation either in subjects who show elevation in speech or those who do not. However, it cannot be stated that the technique simply did not "work," since in some subjects palatal elevation was in fact produced with some consistency. To consider, in sequence, the questions which prompted the study:

1. Does electrical stimulation result in palatal elevation which cannot be elicited via simple tactile stimulation?

The data indicate that electrical stimulation at tolerable intensity levels can elicit palatal elevation but only in some subjects. The subjects who showed response represented each of the three subject groups: normals, palatal pathologies with velopharyngeal competency for speech, and palatal pathologies with incompetency for speech. Thus the data failed to indicate any differences in answer to this question with regard to type of subject.

2. Does the amount of elevation obtained with electrical and tactile stimulation vary with the point of stimulation?

Responses to tactile stimulation were too few and too sporadic to reveal a trend for differences in responses according to site of stimulation.

Subjects with palatal pathologies (CD, JB and CR) showed a trend towards greater response to stimulation of the left and right of the palate than at the midline. The reduced responsiveness to stimulation at the midline in these subjects may have been related to the presence of midline structural abnormality and/or scar tissue. However, to ascribe reduced responsiveness to stimulation at the midline strictly to midline anatomic abnormality may be misleading: It is possible that, if a larger number of non-cleft subjects had shown response to the stimulating current, a similar trend towards greater response to stimulation on the left and right sides of the palate might have emerged.

3. How does the amount of elevation obtained on electrical stimulation vary in relation to strength of current?

These data do not permit a statement regarding the relationship between strength of current and amount of elevation obtained on electrical stimulation. The subjects who showed response to stimulation shared no generalized trends (see Table 2). Actually, inter-subject comparison with regard to differential response to the lower and higher intensities of stimulating current is inadvisable for three reasons:

a. The original procedure for determining the intensity threshold for elicitation of palatal elevation was found to be unsound. Thus, the information gathered on each subject did not include precise assessment of that intensive level at which a sufficient number of motor neurons were caused to fire so as to effect palatal elevation.
b. No attempt was made to determine stimulus characteristics requisite to the production of adaptation, fatigue, artificial tetanus, etc.
c. Even if the physiologic parameters listed above had been determined as part of the procedure, the values obtained undoubtedly would have varied from subject to subject. Possible bases of individual variation in response to the stimulating current are discussed below.

4. What is the relationship between sensitivity to the stimulating current and those intensity levels required to produce response?

The data on the 5 subjects showing response to electrical stimulation indicate that the technique of stimulation as used in this study was effective in producing palatal elevation only when stimulation levels equalled or exceeded the threshold of discomfort. However, it should be noted that a total of 17 subjects from all three subject groups received at least one set of stimuli at or above their discomfort thresholds, yet only 5 showed response.

The lack of a delineable relationship between sensitivity to current and the current level required to produce elevation is not unexpected. The purpose of electrical stimulation as used with innervated musculature is to stimulate motor, not sensory (i.e., touch, pain) nerves (*2*, *4*, *13*). No intrinsic connection would thus be expected between the intensity at which a subject indicated discomfort and the intensity required to elicit a movement response. The fact that the 5 subjects showing identifiable patterns of response to electrical stimulation responded only at current levels equalling or exceeding their discomfort thresholds suggests a relationship that is more apparent than real: The requisite intensity for elicitation of palatal elevation indeed equalled or exceeded the discomfort threshold but no cause-effect relationship is inferred since excitation of feeling and elicitation of movement involve two different systems.

It is pertinent at this point to recall the work of Yules and Chase (*32*). In a personal communication (*31*), Yules reported that the average intensity level for intraoral stimulation as used in their training program was 1.0 ma. The present data suggest that a single application of a 1.0 ma current would be far too low to elicit palatal elevation. However, it is difficult to compare the intensity levels used in this study with those used by Yules and Chase because the stimulator used in the present study was modified (to achieve a specific waveform) while the same model stimulator used by Yules and Chase apparently was not modified.

5. How does the amount of elevation obtained on electrical stimulation compare with that shown on a non-speech maximum closure task? On a speech task?

In 4 of the 5 subjects who showed response to electrical stimulation, all velar height values on responses to stimulation fell below the velar height values on blowing on manometer with bleed. (The 5th subject, CD, did not break tongue-palate contact during the blowing task.) For all 5 subjects, VH values on responses to stimulation tended to fall between the values on /mɑmɑ/ and /fufu/.

Theoretical Bases for Lack of Consistent Response to Electrical Stimulation. There are a number of possible explanations for the failure to obtain consistent response to electrical stimulation in the subjects in this study. Among the methodological points which must be taken into account are (1) the use of surface rather than needle electrodes, (2) the possibility that the "threshold" for elicitation of a response was simply never reached with the majority of subjects, and (3) the possibility that other sites of stimulation and/or another waveform might have been more effective.

Limitations of cinefluorographic observation must also be considered. Lateral cinefluorography restricts observations of the anatomic structures primarily to the mid-sagittal plane. If differential velar movements were to occur at various points across the surface of the palate, such movements might be undetectable on the mid-sagittal films. Further, very small degrees of movement could go unnoticed by even experienced viewers.

Another possible explanation for the inconsistent results lies in anatomic and behavioral differences among subjects. Anatomic bases for inter-subject variability in response include (1) differences in amount and type of tissue through which the current must pass to stimulate efferent neurons, and (2) differences in insertion of the levator into the soft palate.

Variation in what may be called "unstimulated behavior" of the velopharyngeal musculature may have contributed to the inconsistency in results both within and among subjects. No data are available regarding random movements of this musculature over time. Within a given subject, a movement which was interpreted as a response to stimulation may have been simply a "random" movement occurring coincidentally with the stimulus. Such a possibility appears particularly likely in those subjects who showed only one or two responses throughout the stimulation procedure. Further, there may have been significant inter-subject variability in such behavior.

COMMENTS: CLINICAL USE. The present results suggest that a technique of electrical palatal stimulation devised with patient comfort as a prerequisite, i.e., using surface (not needle) electrodes and intensity levels below pain threshold, will not reliably result in palatal elevation. Future adoption of electrical stimulation such as used in the present study as a clinical tool appears particularly unlikely in view of the fact that palatal elevation was elicited only in subjects who already showed elevation in speech. While electrical stimulation through needle electrodes has resulted in levator contraction in the laboratory (7), a practical means for obtaining such results in a clinical setting has yet to be devised.

Summary and Conclusions

The purpose of the present study was to gather descriptive data related to the question of whether palatal elevation could be elicited by permucosal electrical stimulation applied to the oral surface of the soft palate. Nineteen subjects (9 normals, 5 with palatal pathologies but velopharyngeal competency for speech, and 5 with velopharyngeal incompetency for speech) received tactile and electrical stimulation of the soft palate while being filmed by cinefluorography. Tactile and electrical stimuli were delivered at three loci on the palate by a pencil electrode. The tactile stimulation served as a "placebo" condition for comparison with the effects of electrical stimulation. An additional normal subject received tactile stimulation only. The surged faradic current was delivered at intensities predetermined according to each subject's sensitivity and discomfort thresholds. The cinefluorographic films also included blowing and speech samples to allow comparison of palatal activity on these tasks with that elicited by the stimuli. The results led to the conclusion that electrical stimulation using surface electrodes and current intensities below pain threshold will

not reliably result in palatal elevation. Development of electrical palatal stimulation as a clinical tool will be dependent upon practical adaptation of laboratory-proven techniques.

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